# QCD RESULTS AT CDF

OLGA NORNIELLA*
*Institut de Física d'Altes Energies,*
*Edifici Cn. Facultat Ciències UAB,*
*E-08193 Bellaterra (Barcelona), Spain*
*E-mail: onorni@ifae.es*

Recent QCD measurements from the CDF collaboration at the Tevatron are presented, together with future prospects as the luminosity increases. The measured inclusive jet cross section is compared to pQCD NLO predictions. Precise measurements on jet shapes and hadronic energy flows are compared to different phenomenological models that describe gluon emissions and the underlying event in hadron-hadron interactions.

## 1. Introduction

The Run II at the Tevatron $p\bar{p}$ collider will define a new level of precision in the knowledge of QCD processes in hadron collision. The large amount of data to be collected in Run II, together with the increase in the center-of-mass energy (from 1.8 to 1.96 TeV) and the upgrade of the CDF detector [1] will allow to perform stringent tests of the QCD predictions in extended regions of jet transverse momentum, $P_T^{\rm jet}$, and jet rapidities, $Y^{\rm jet}$.
This contribution presents recent results on inclusive jet production, as well as studies on non-perturbative QCD phenomena related to jet fragmentation and the underlying event.

## 2. Inclusive Jet Cross Section

The measurement of the inclusive jet production cross section is one of the pillars of the QCD program at CDF. It probes very small distances ($10^{-19}m$) and thus is sensitive to new physics. In the Run II, the cross section has increased (by a factor of 5 for jets with $P_T^{\rm jet} > 600$ GeV/c) compared to the Run I. This has allowed already to increase the kinematic

*On behalf of the CDF Collaboration.

region in $P_T^{\rm jet}$ by more than 150 GeV/c. Following theoretical work, CDF is exploring the $K_T$ algorithm [2] in order to search for jets:

$$K_i = P_{T,i}^2; \qquad K_{ij} = min(P_{T,i}^2, P_{T,j}^2) \cdot \frac{(Y_i - Y_j)^2 + (\phi_i - \phi_j)^2}{D^2} \qquad (1)$$

where the jets are separated according to their relative transverse momentum. The algorithm includes a D parameter that approximately controls the size of the jet in the $\phi - \eta$ space. Unlike the Run I cone-based jet algorithm [3], the $K_T$ algorithm is infrared and collinear safe to all orders in perturbative QCD and does not need an experimental prescription to resolve situations with overlapping cones. Figure 1 shows the inclusive jet cross section using the $K_T$ algorithm, in the region $0.1 < |Y^{\rm jet}| < 0.7$ and based on the first 145 pb$^{-1}$ of Run II data.

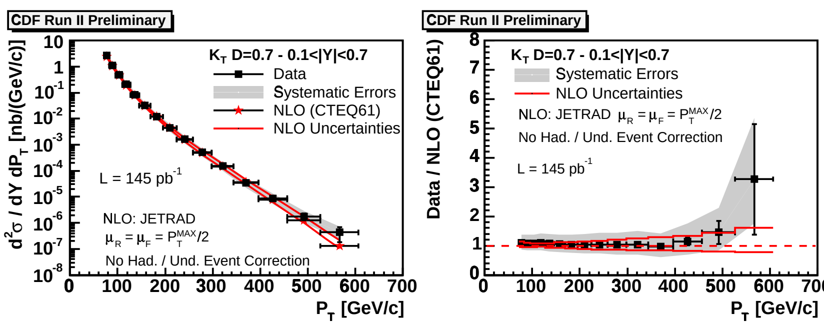


Figure 1. Measured inclusive jet production cross section compared to pQCD NLO predictions for a D parameter equal to 0.7.

The measurement is compared to pQCD NLO calculation as determined using JETRAD program [4], with CTEQ 6.1 PDFs [5] and the renormalization and factorization scale set to $P_T^{\rm max}/2$. The data uncertainties are dominated by the energy scale determination in the calorimeter, while the NLO errors mainly come from the gluon PDFs. The agreement between data and NLO is good. At low $P_T^{\rm jet}$, the data tends to be above the prediction and the effect increases as D increases (see Figure 2). This indicates the presence of underlying event contributions and fragmentation effects that have not been taken into account yet.

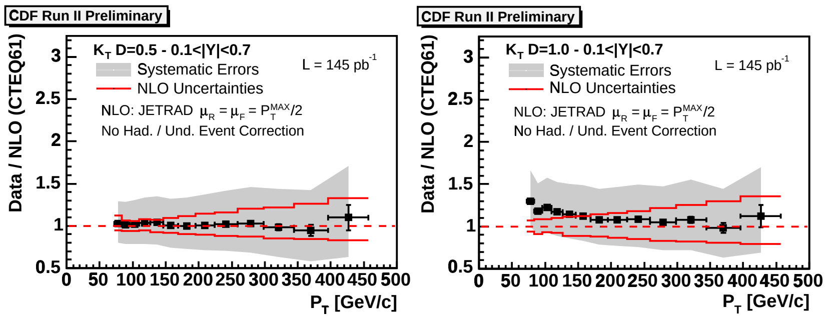


Figure 2. Data divided by pQCD NLO predictions using D=0.5 and D=1.0, respectively.

## 3. Study of the Underlying Event

As mentioned, the final states in hadron collision are affected by the presence of soft gluon emissions. The underlying event receives contributions from initial and final-state soft gluon radiation, beam-beam remnants and multiple parton interactions. These processes must be modeled using MC programs tuned to describe the data. In CDF, the underlying event has been studied in dijet production by looking at different regions (in $\phi$) well separated to the direction of the leading jet (see Figure 3-left). The "transverse" region is perpendicular to the direction of the hard 2-to-2 scattering and is assumed to be mostly sensitive to the underlying event. Figure 3-right shows the averaged charged particle density in the transverse region as a function of the $E_T^{\rm jet}$ of the leading jet. The jets are defined by the Run I cone-based jet algorithm with a cone size R=0.7. The measurement has been restricted to events in which the leading jet is in the region $|\eta^{\rm jet}| < 2.0$ with $E_T^{\rm jet} > 15$ GeV. The measurements are repeated using dijet events with nearly back-to-back configuration in $\phi$, with the aim to suppress extra hard gluon radiation.

The measurement is compared to different MC models: Pythia tune A [6] and Herwig [7]. It shows that the underlying event contribution in the transverse region is well described by Pythia tune A, while Herwig does not describe the low $P_T^{\rm jet}$ region as well as Pythia. The latter can be attributed to the absence of multiple parton contributions in Herwig.

## 4. Studies on Jet Shapes

The study of the jet shape is also sensitive to the underlying event. The shape of the jet is dominated by multi-gluon emission from the primary

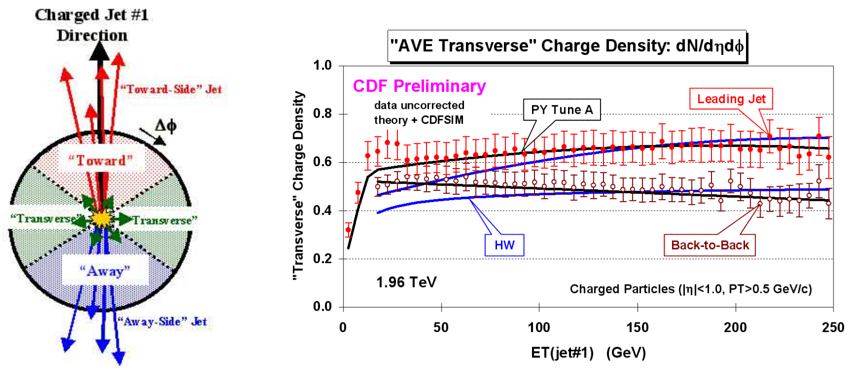


Figure 3. *Left:* Definition of the transverse region in $\phi$. *Right:* Measured average charged particle density in the "transverse region" as a function of $E_T^{\rm jet}$ of the leading jet compared with different MC models.

parton and it constitutes a test of the parton shower models and their implementation in the MC programs. The integrated jet shape is defined as the average fraction of the jet transverse momentum that lies inside a cone of radius r concentric to the jet cone:

$$\Psi(r) = \frac{1}{N_{jet}} \sum \frac{P_T(0,r)}{P_T(0,R)}, \qquad 0 \leq r \leq R \tag{2}$$

Figure 4-left presents the measured integrated jet shape for jets defined using the Midpoint algorithm [9] with a cone size R=0.7 in the region 37 GeV/c $< P_T^{\rm jet} <$ 45 GeV/c. The measurements have been done for jets with $P_T^{\rm jet}$ in the region 37 GeV/c $< P_T^{\rm jet} <$ 380 GeV/c. The measurements have been compared to the prediction from Pythia-tune A and Herwig MCs. In addition, two different Pythia samples have been used with default parameters, with and without multiple parton interaction, in order to study the importance of a proper modeling of soft-gluon radiation. Figure 4-right shows, for a fixed radius r=0.3, the average fraction of the jet transverse momentum outside r=0.3 as a function of $P_T^{\rm jet}$.

The measurements show that the jets are narrower as $P_T^{\rm jet}$ increases. Pythia tune A predictions describe all of the data well, while Herwig produces too narrow jets at low $P_T^{\rm jet}$. The comparison between Pythia and Pythia (no MPI) indicates that the contribution from the multiple interactions on the jet shapes is relatively small but relevant at low $P_T^{\rm jet}$.

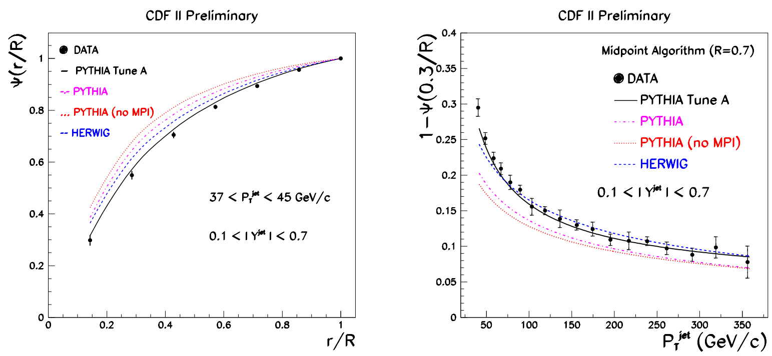


Figure 4. Measured integrated jet shape compared to different MC predictions.

## 5. Conclusions

Preliminary results on the inclusive jet cross section have been presented in this contribution. The measurements are in agreement with pQCD calculations. Several studies have been done in order to test the modeling of the soft gluon radiation and the underlying event in the different MC programs. The results show that Pythia tune A prediction provides the best description of these non-perturbative QCD phenomena.

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